AFTA Coronagraph (non-VNC) Modeling Update

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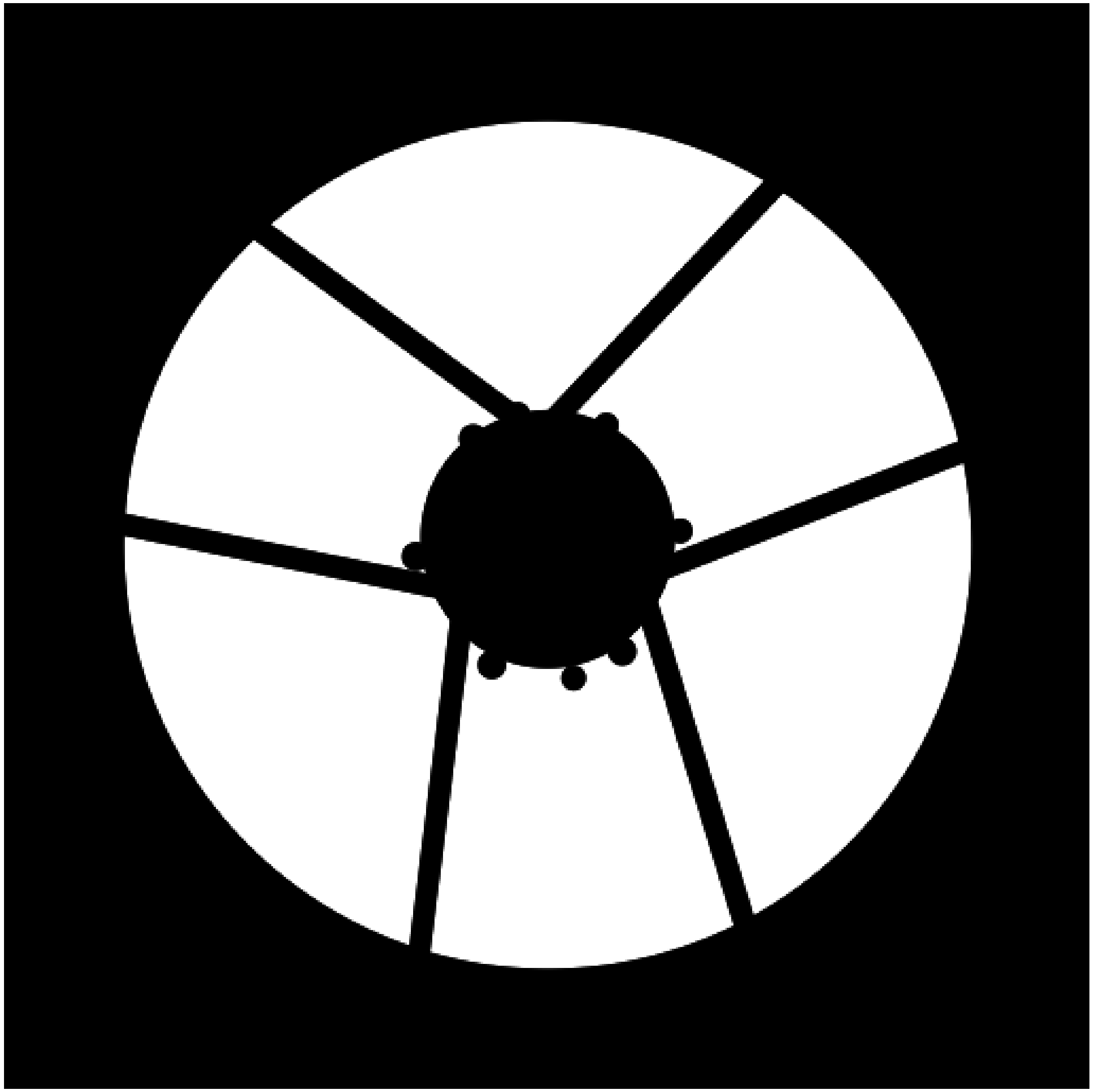
27 September 2013

Modeling Status (non-VNC)

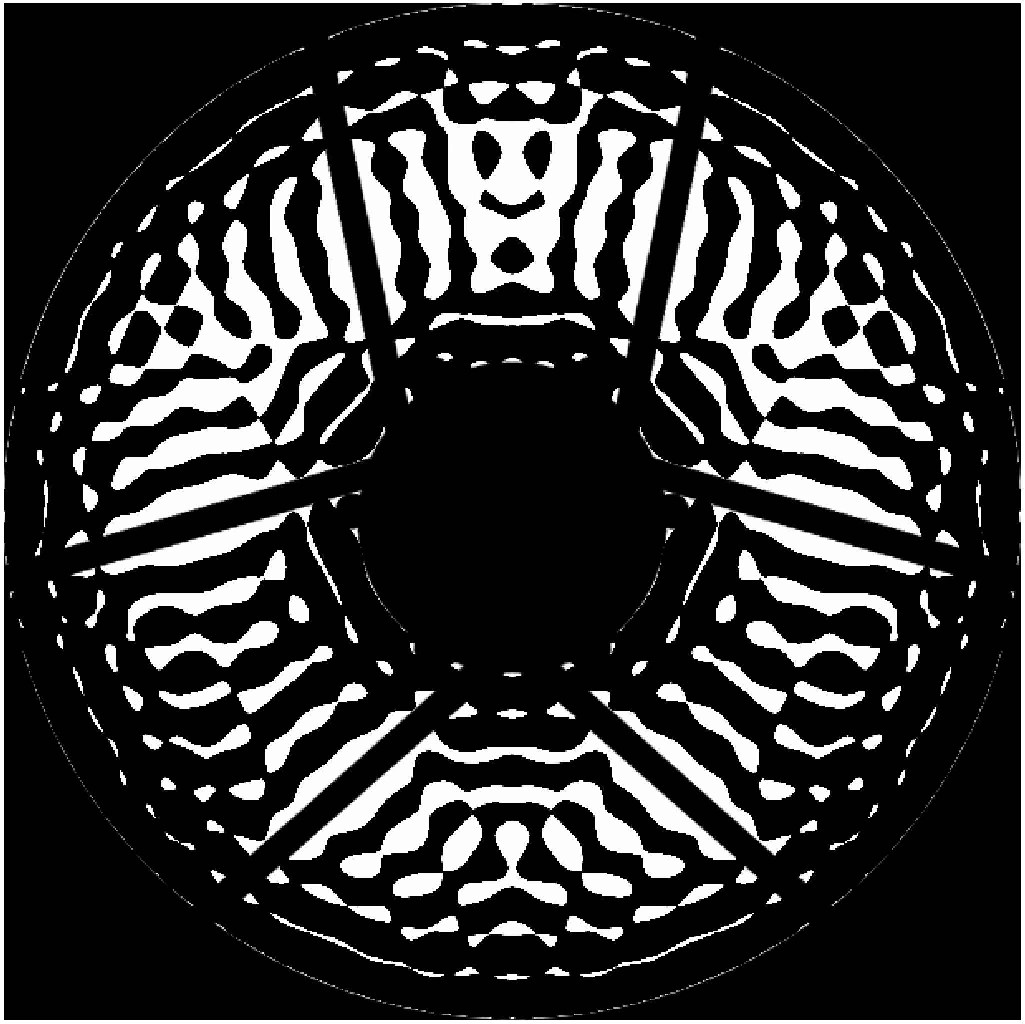
- Lyot/VVC/shaped pupil layout delivered
  - Zemax prescription unfolded for use by PROPER
  - Alterations required to enforce 48 mm diameter pupil at DM 1 and collimated beam to DM 2
  - Phase & amplitude errors generated for each optic
  - Off-axis aberrations and distortions not included in PROPER models
- A variety of shaped pupils were delivered late last week
  - Discovery (360˚ field) and characterization (57˚ dual field)
  - End-to-end modeling in the AFTA aberrated system performed
  - NOT directly compatible with official AFTA pupil (but close)
- Monochromatic PIAA solution delivered on Tuesday
  - For verification of modeling results
- Early (unofficial, pre-Princeton meeting) HLC evaluated
- Non-optimal monochromatic vector vortex investigated
- ACAD remapping propagation methods investigated

The Enemy



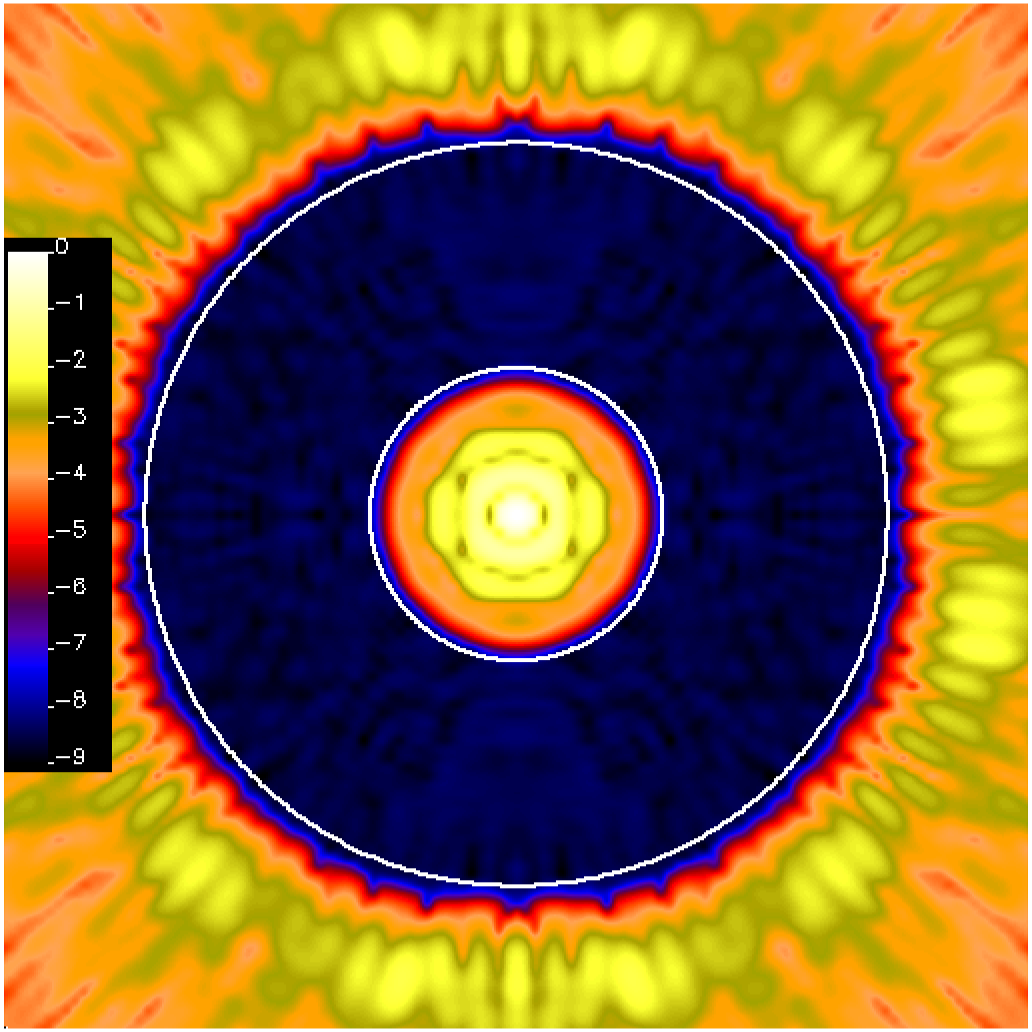
Discovery Mask

Transmission = 26% relative to AFTA obscured pupil



No aberrations

Mean contrast = 3.1 x 10^{-9}



Circles = 6.5 & 16.5 λ/D

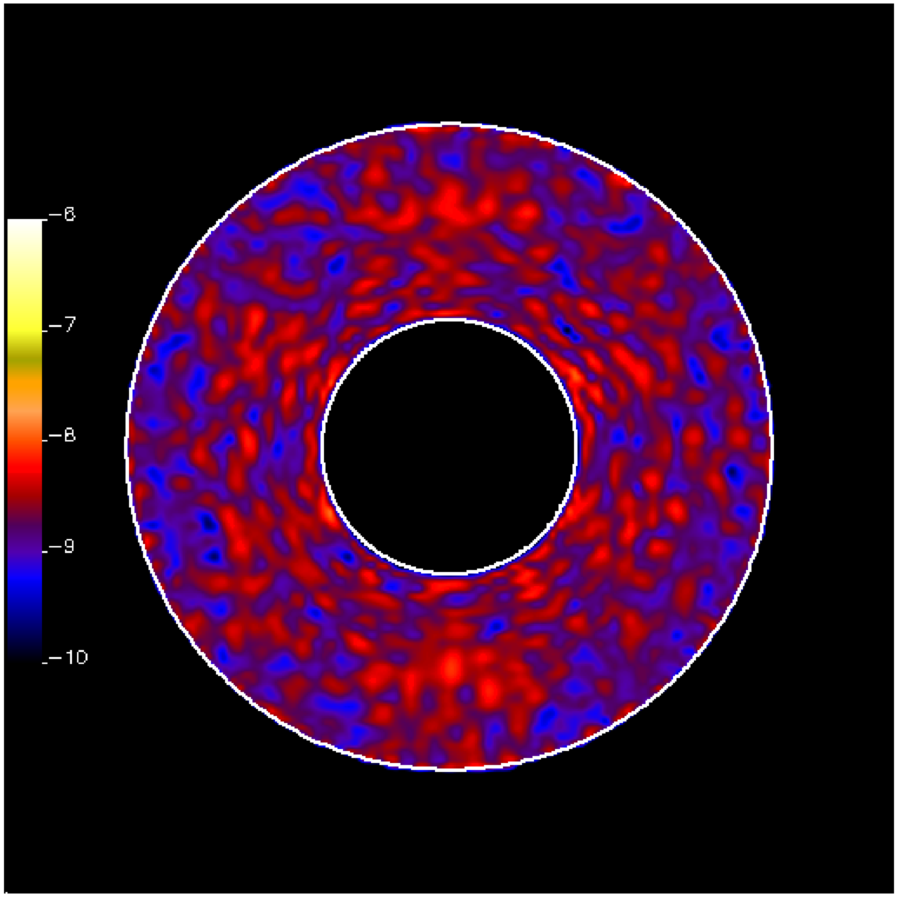
Discovery Shaped Pupil Evaluation

- Evaluated over $\lambda = 522 - 578$ nm, $\lambda_c = 550$ nm
- Sensing & control at 5 wavelengths spanning bandpass
- Measurement field: $6.5 < r < 16.5\ \lambda_c/D$
- All contrast maps & measurements shown are broadband
- Mask at 1st pupil after DMs, field stop at following focus

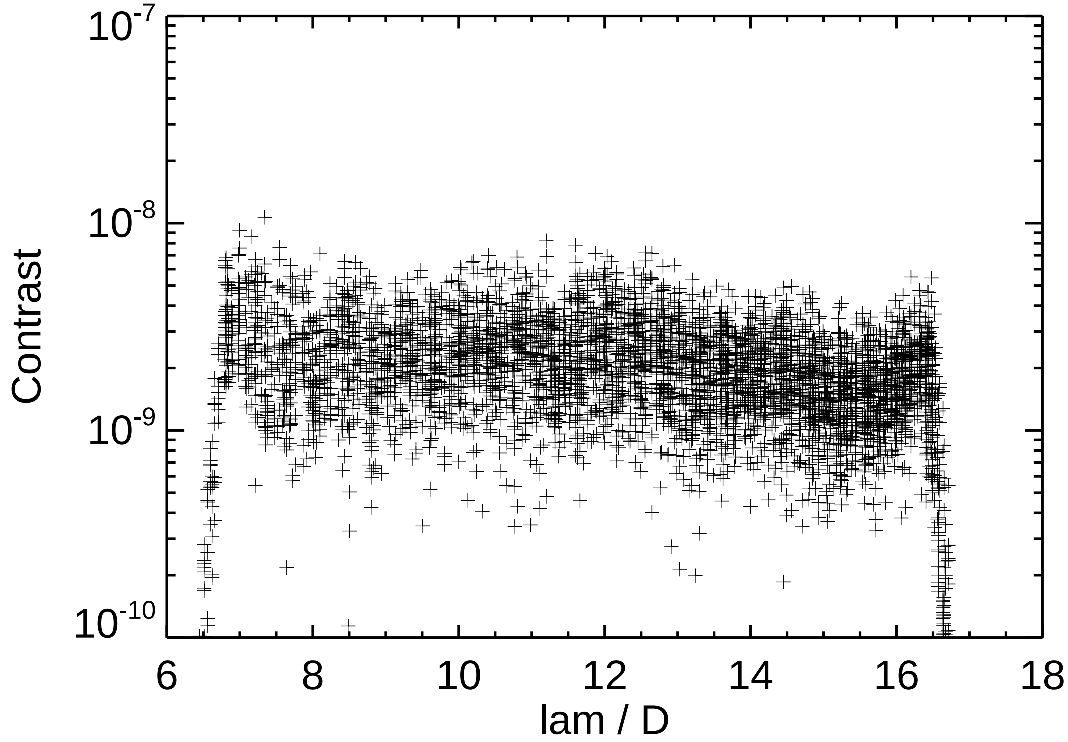
After EFC

Aberrations on all optics

Mean contrast = 2.2 x 10^{-9}



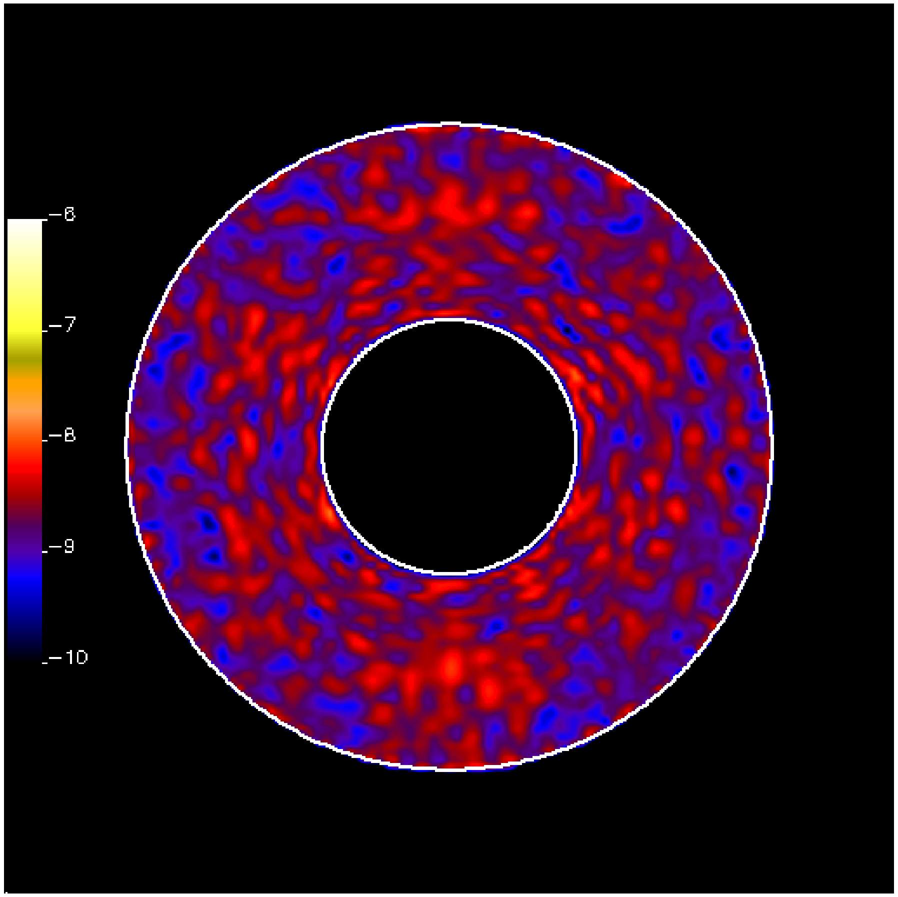
Circles = 6.5 & 16.5 λ/D



After EFC

All synthetic error maps

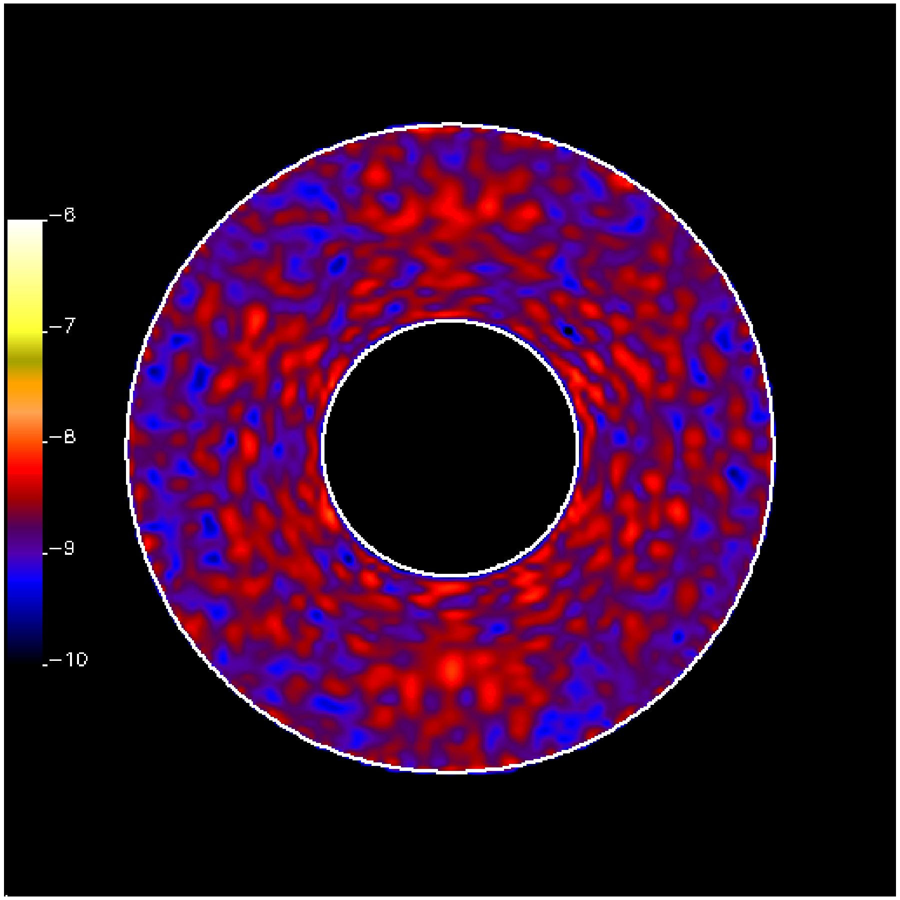
Mean contrast = 2.2 x 10^{-9}



Circles = 6.5 & 16.5 λ/D

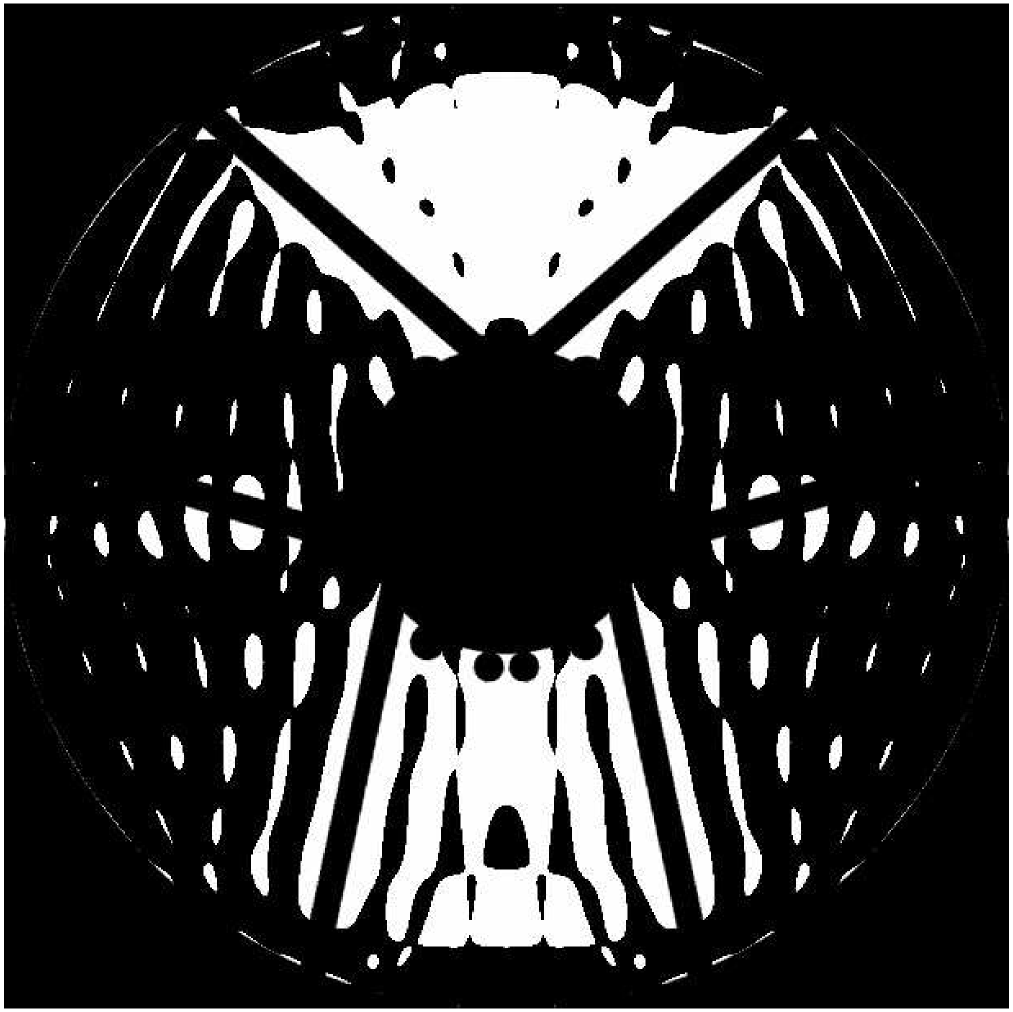
Measured primary & secondary error maps

Mean contrast = 2.1 x 10^{-9}



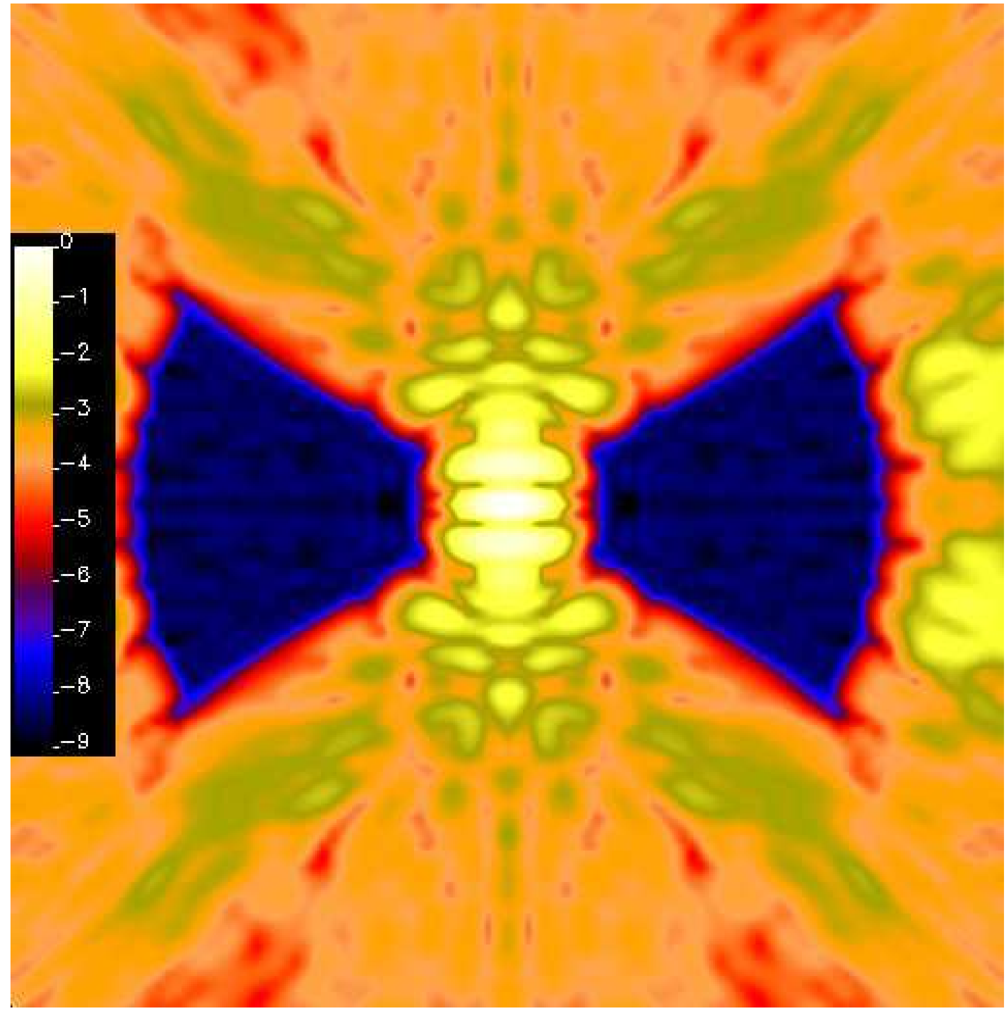
Characterization Mask

Transmission = 29% relative to AFTA obscured pupil



No aberrations

Mean contrast = 5.3 x 10^{-9}



Characterization Shaped Pupil Evaluation

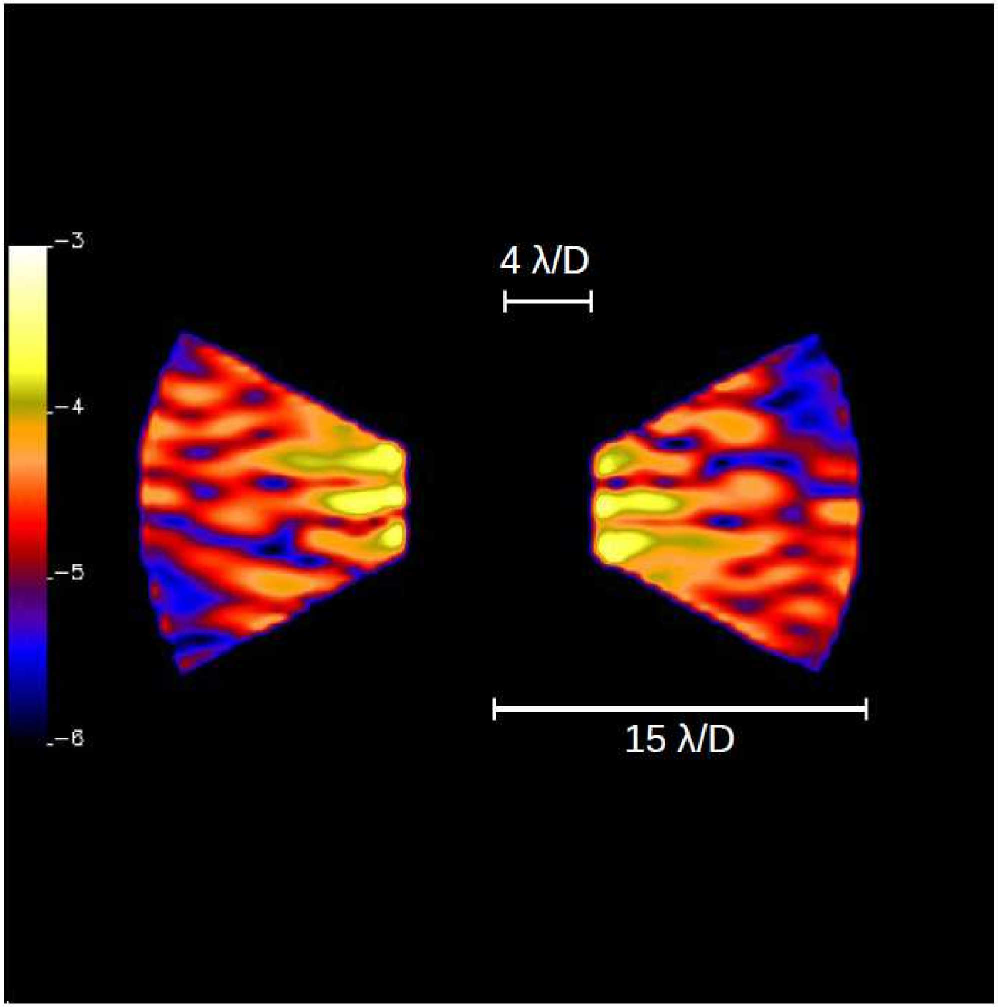
- Evaluated over $\lambda = 522 – 578$ nm, $\lambda_c = 550$ nm
- Sensing & control at 5 wavelengths spanning bandpass
- Measurement field:
  - $X > 4\ \lambda_c/D$
  - $R < 15\ \lambda_c/D$
- All contrast maps & measurements shown are broadband
- Mask at 1st pupil after DMs, field stop at following focus

Before EFC

Aberrations on all optics

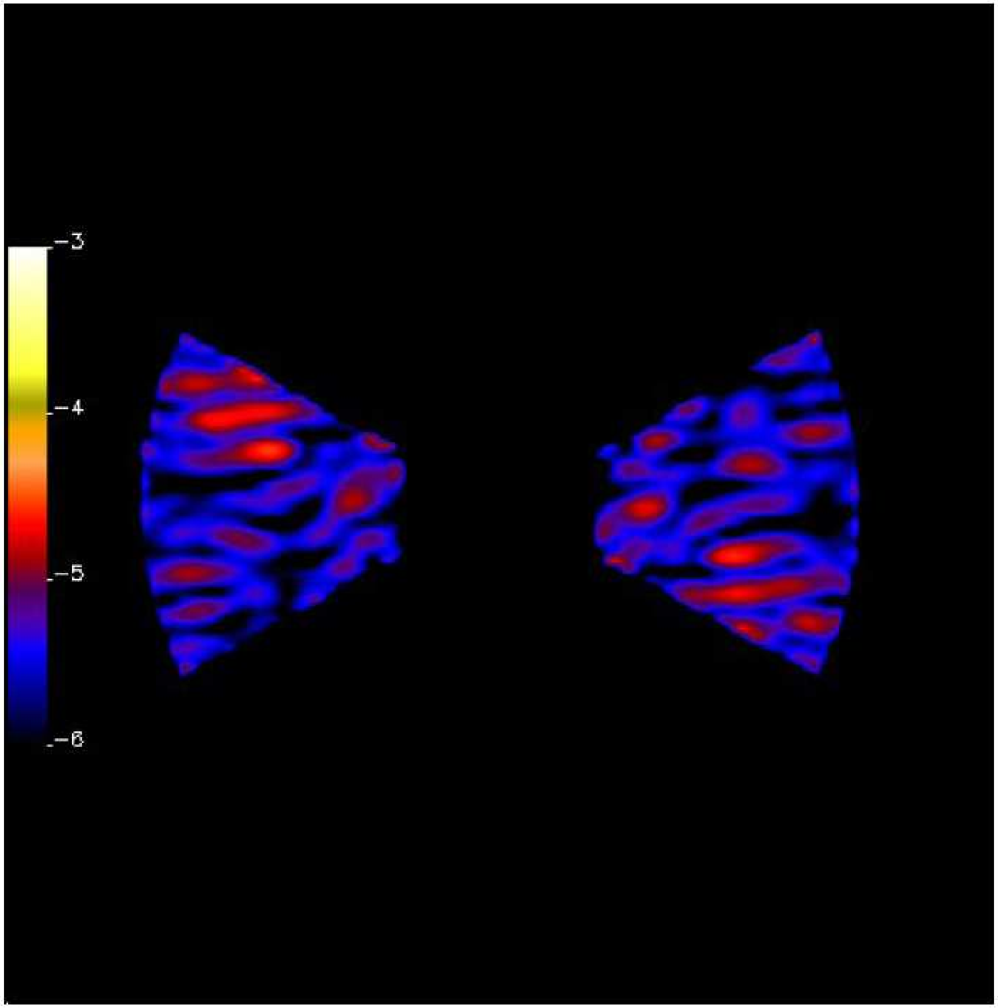
Before wavefront control

Mean contrast = 3.7×10^{-5}



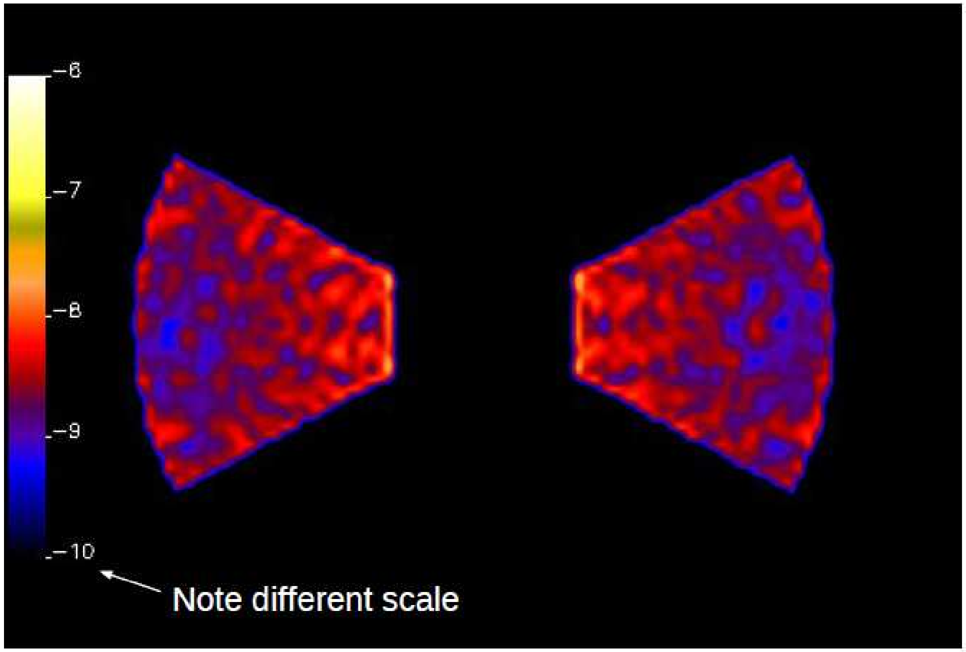
After flattening

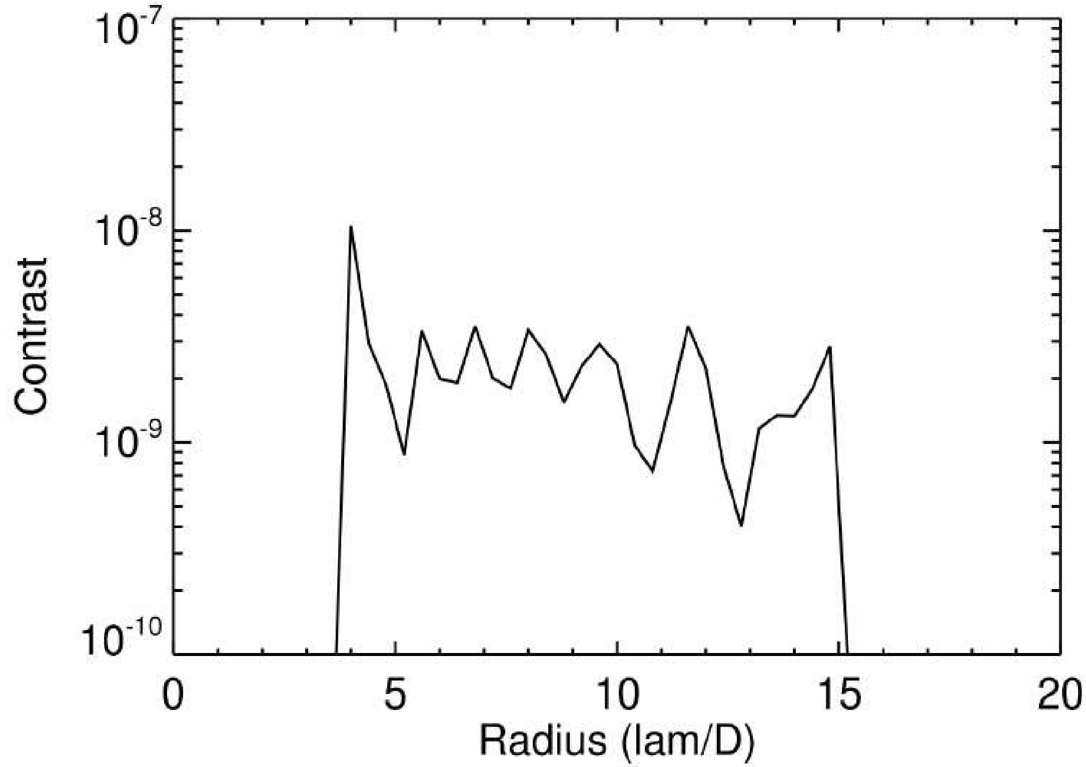
Mean contrast = 4.4×10^{-6}



After EFC

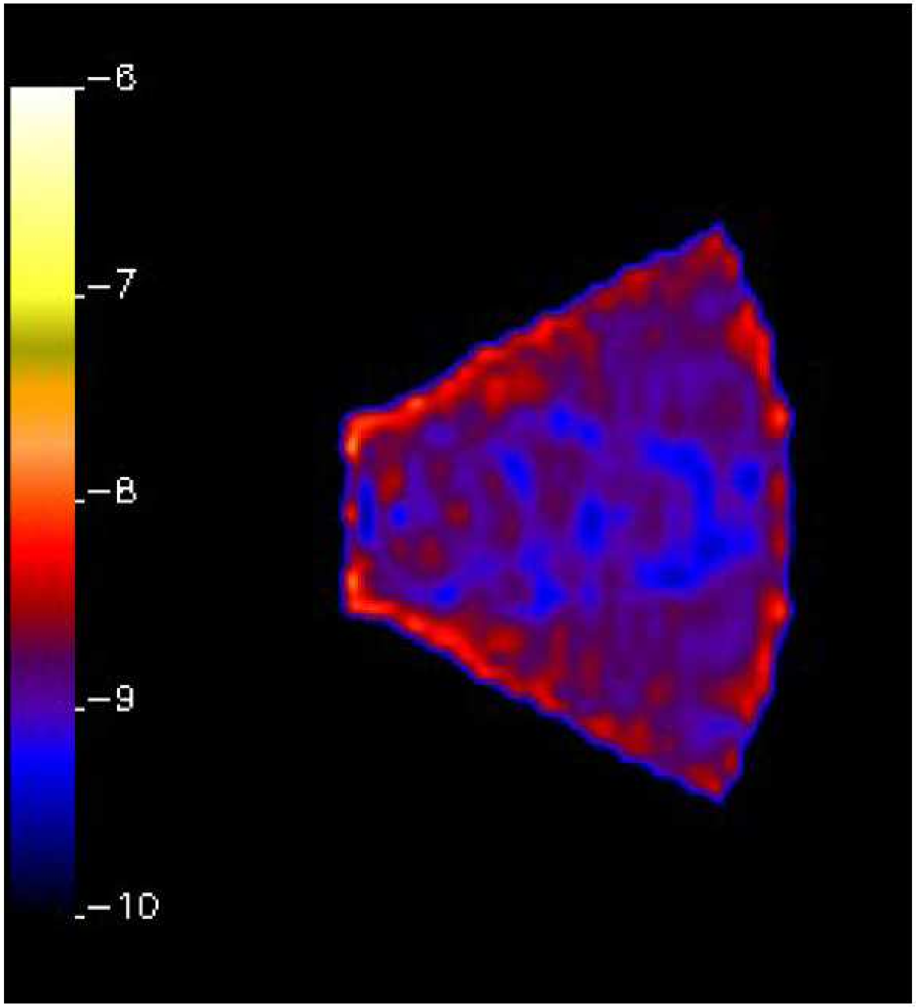
Mean contrast = 2.7×10^{-9}





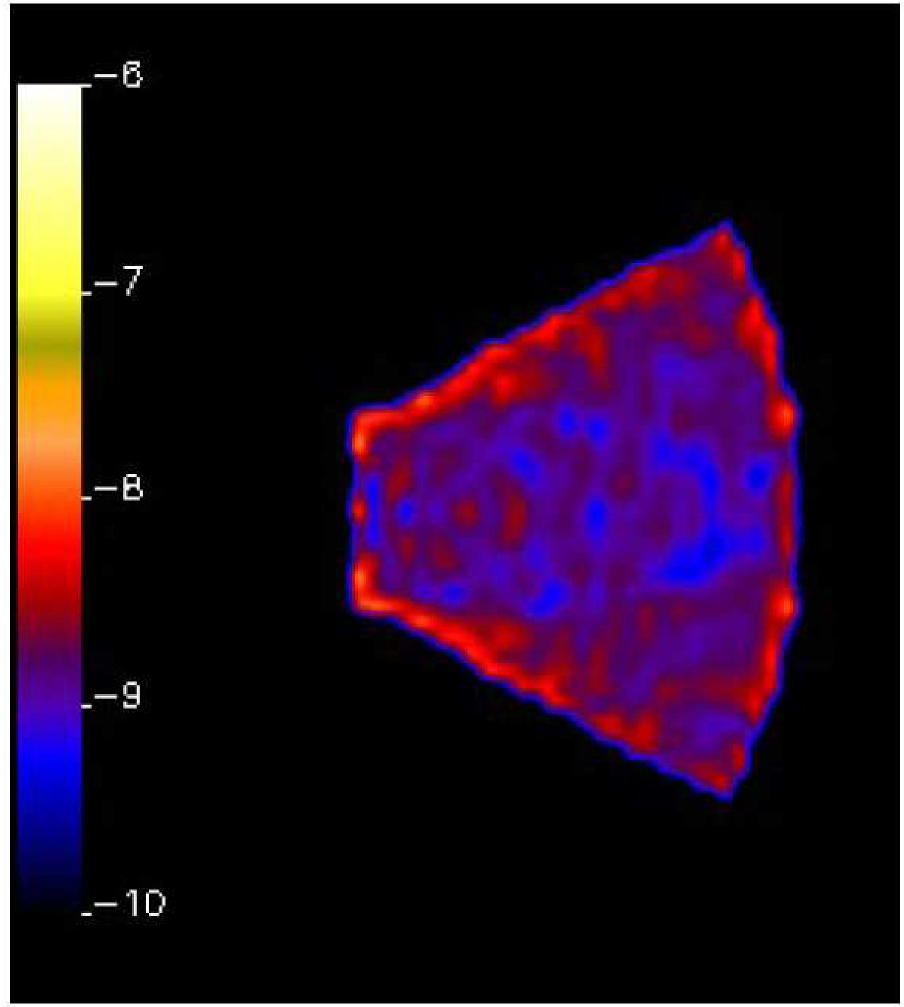
One-sided Dark Hole After EFC

Mean = 1.8 x 10^{-9}



Started with 2-side
DM settings

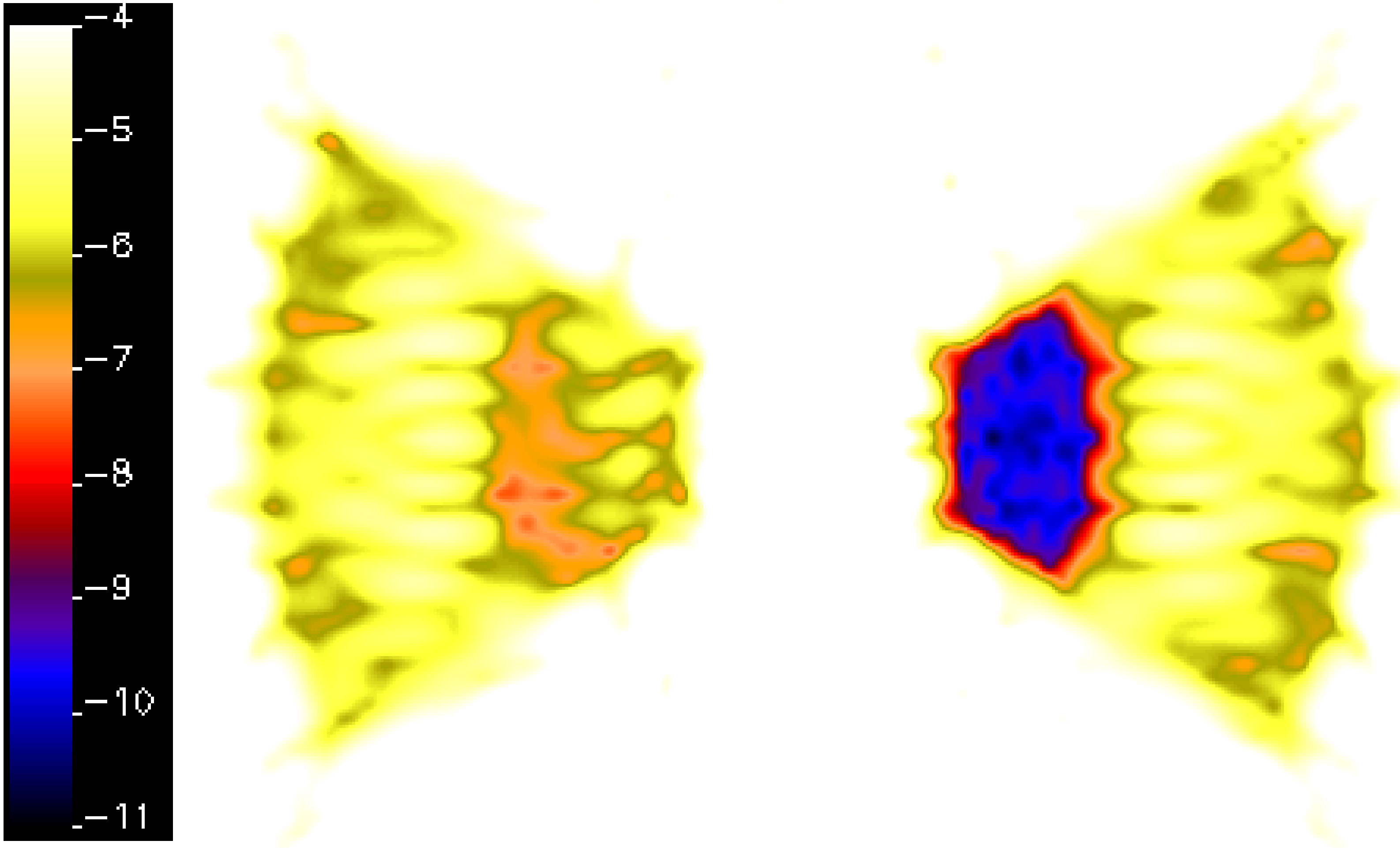
Mean = 1.9 x 10^{-9}



Started fresh with
Flattened wavefront

Smaller Dark Hole: 4 – 8 λ/D

4.8×10^{-10} (4 – 8 λ/D)
6.8×10^{-10} (4 – 5 λ/D)

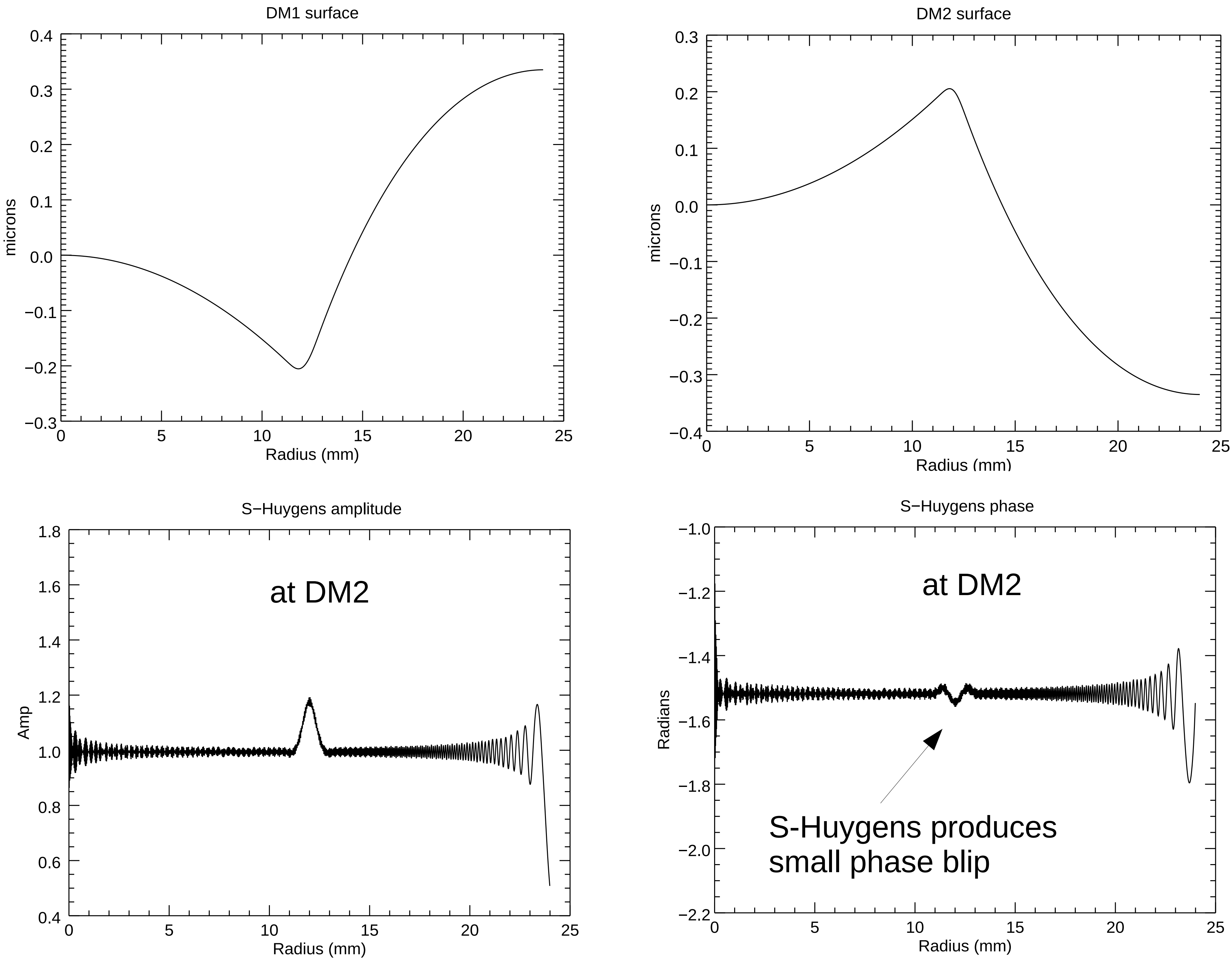


Shaped Pupil Conclusions

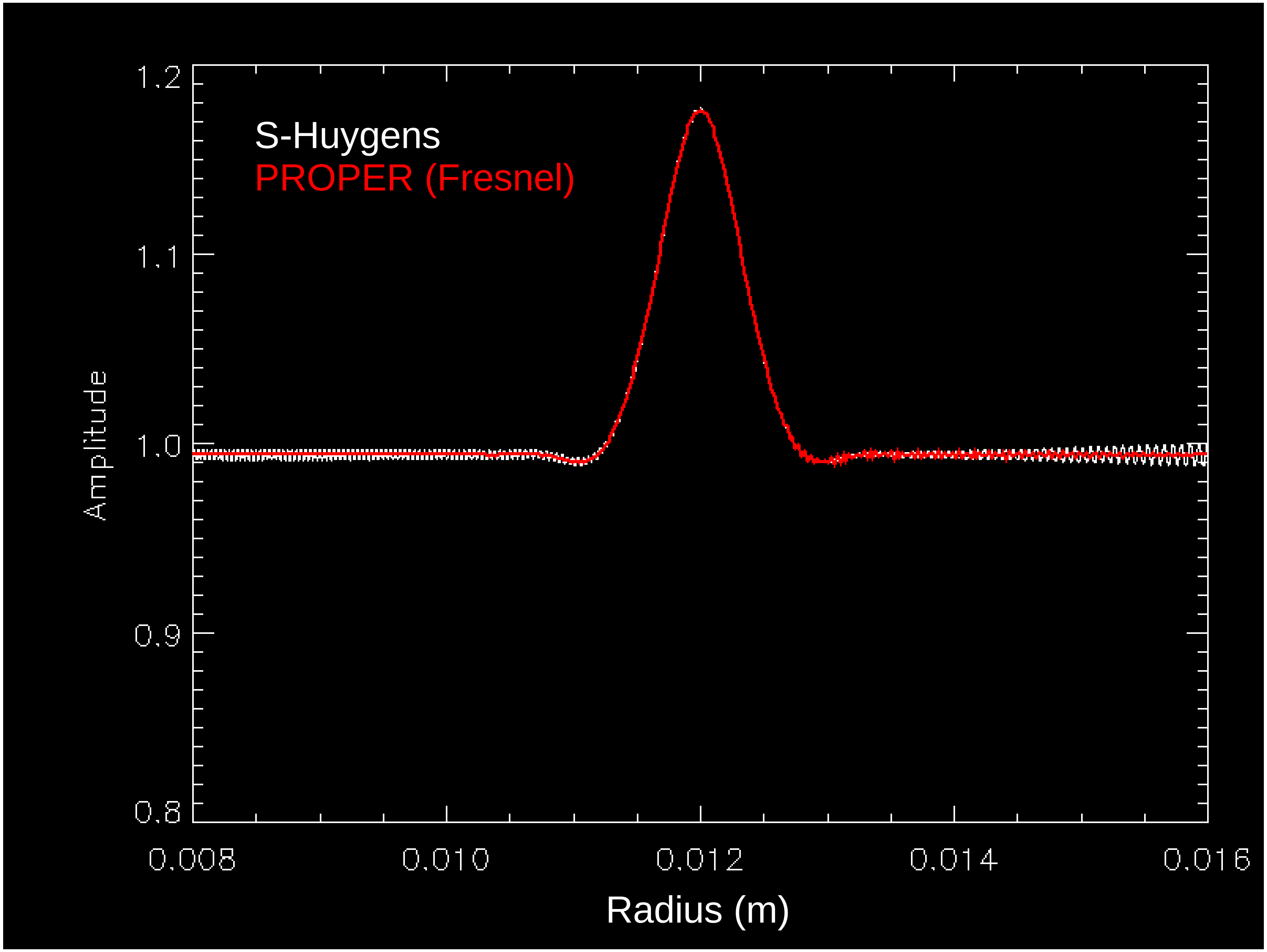
- Achieves 2-3 x 10^{-9} mean contrast over target region, 5-10 x 10^{-9} near IWA
- Broadband (tested over 10%)
- ~25% mask transmission
- Current pupils not exactly matched to official pupil, but very close (do not expect performance to change significantly with official pupil)

Propagation of ACAD DM Patterns

- Remapping/apodization of the spiders by using the DMs requires large total strokes (~0.5 μm)
- Pueyo & Norman (2013) suggested that typical Fresnel propagators would fail to properly account for the large strokes and remapping
- A new propagation algorithm, SR-Fresnel, was devised
    - Combined ray tracing to derive remapping function with supposedly more accurate propagator
    - SR-Fresnel is very slow for propagating an arbitrary input wavefront
    - Tests show 2-D SR-Fresnel algorithm does not properly propagate phase term
- New comparisons with Fresnel and S-Huygens reveal *Fresnel algorithms are accurate for large strokes* of at least a few microns
- Pueyo concurs with this conclusion

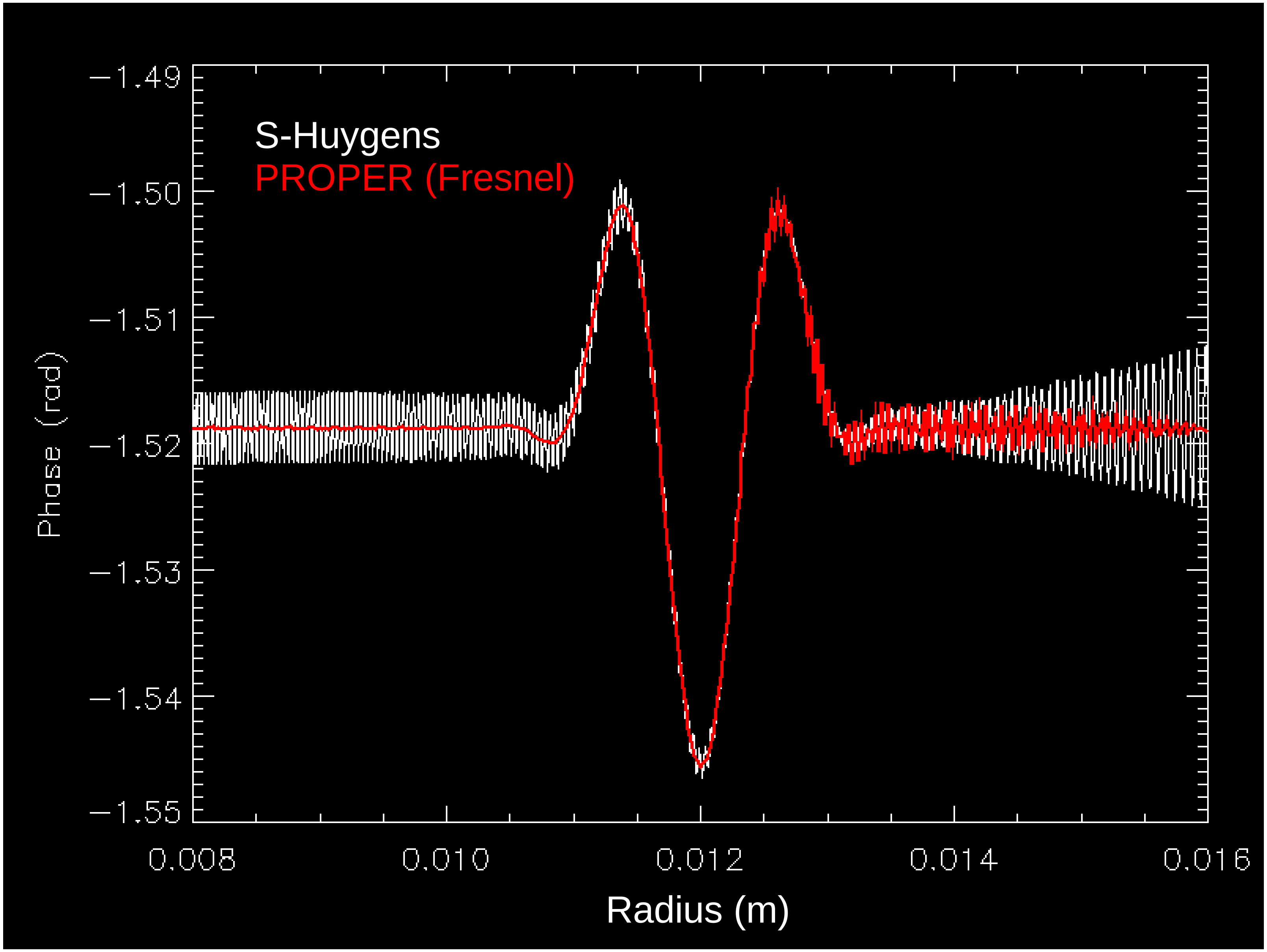

DM1 surface
microns
Radius (mm)
DM2 surface
microns
Radius (mm)
S−Huygens amplitude
at DM2
Amp
Radius (mm)
S−Huygens phase
at DM2
Radians
Radius (mm)
S-Huygens produces
small phase blip

Unobscured, large stroke



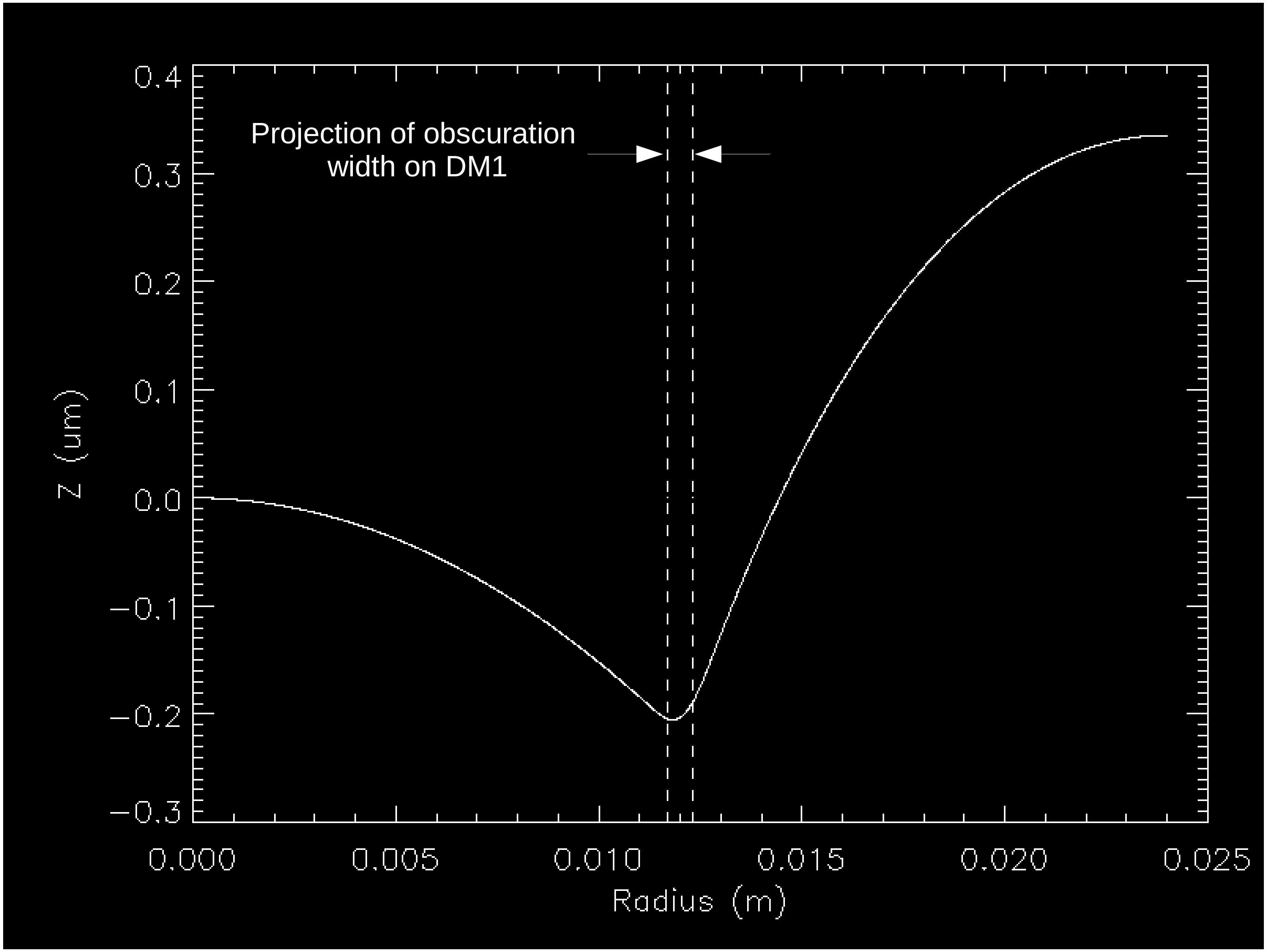
Both S-Huygens and PROPER data are smoothed

Unobscured, large stroke

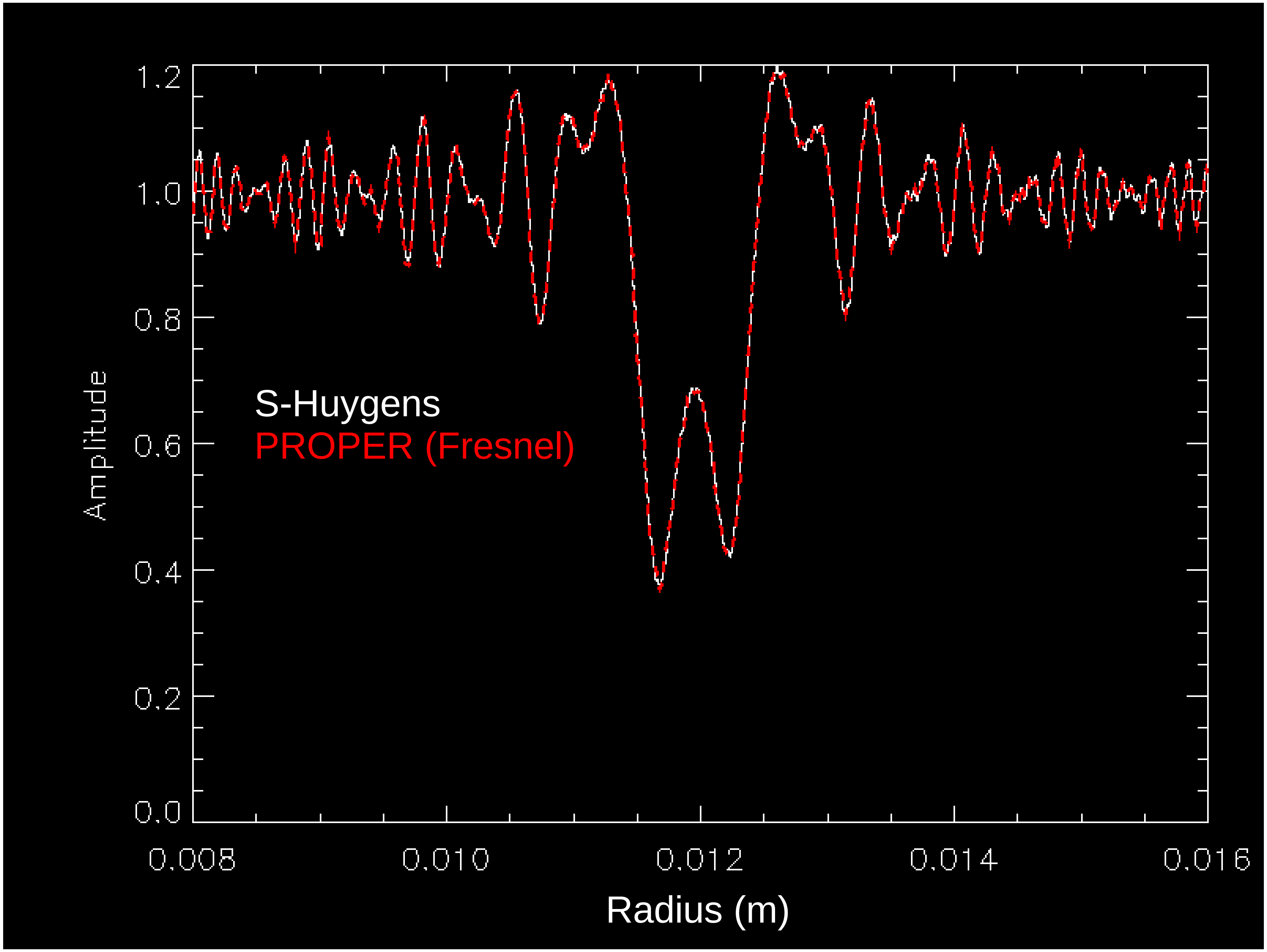


With dark ring

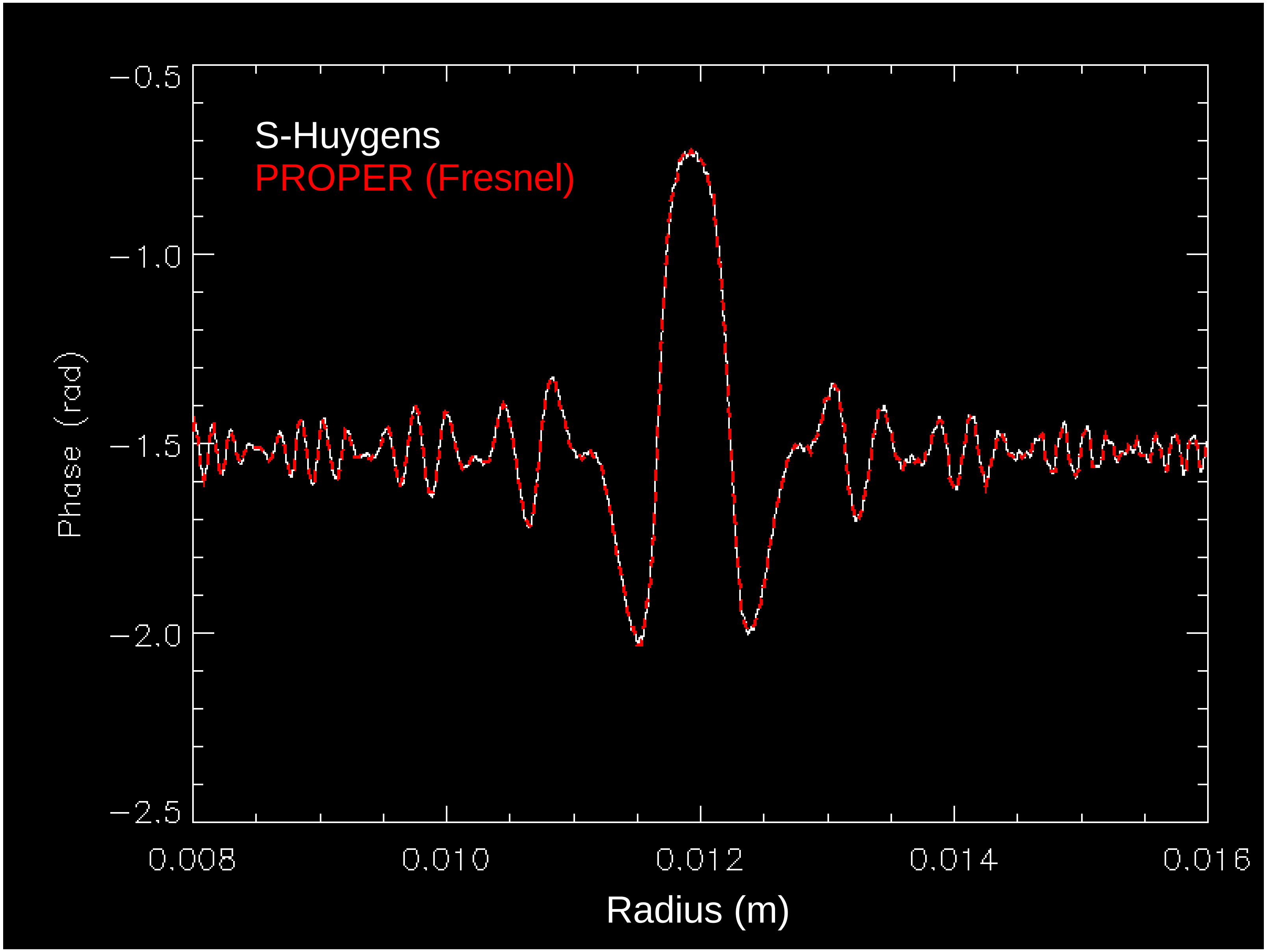
- Add 1.3% (0.32 mm) thick dark ring to initial wavefront at position largest 2nd derivative
- Use large stroke (0.5 um) case
- Propagate with S-Huygens (1-D) and PROPER (2-D)

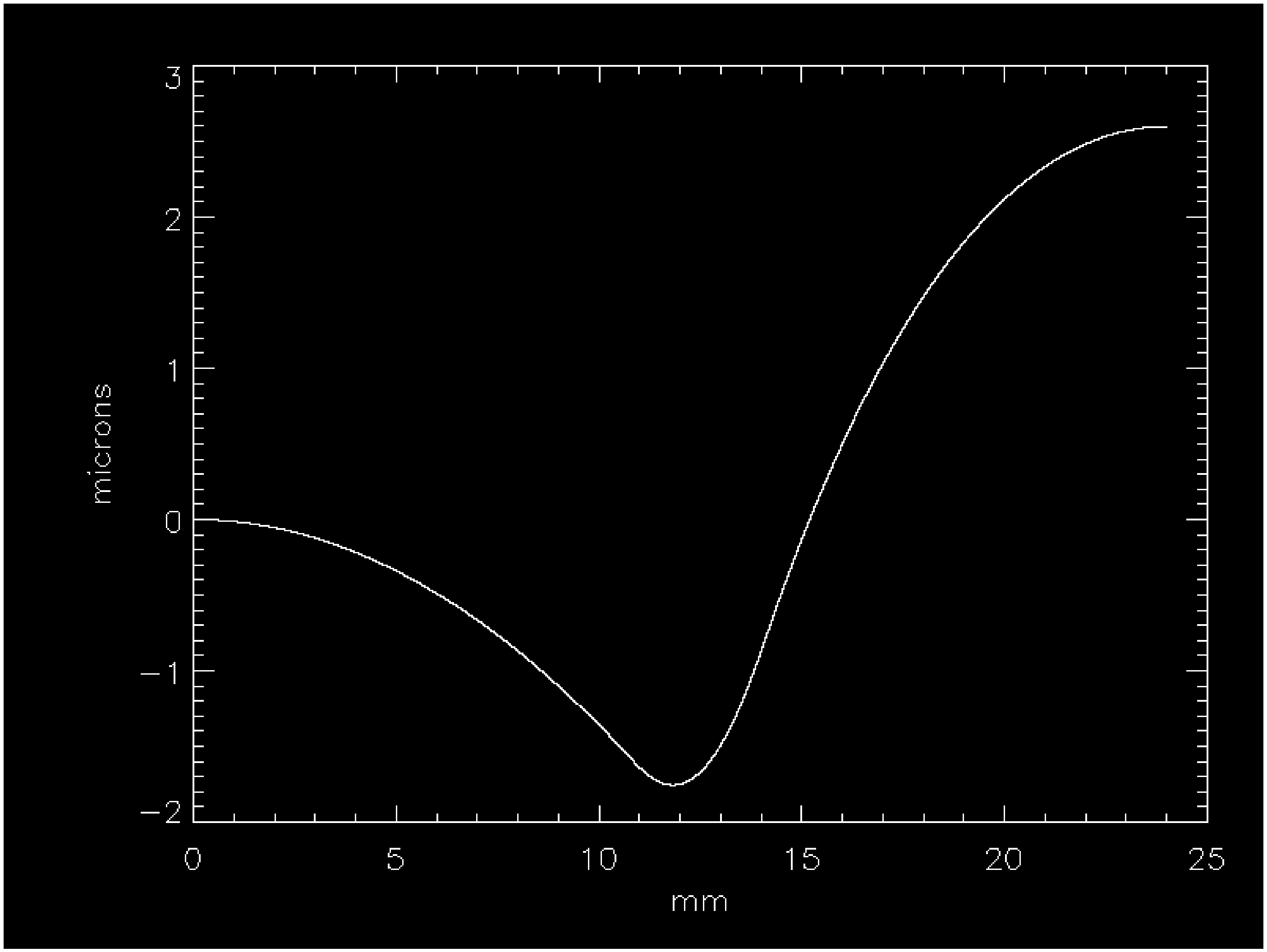

Projection of obscuration width on DM1
Z (um)
Radius (m)
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
0.000
0.005
0.010
0.015
0.020
0.025

Obscured, large stroke

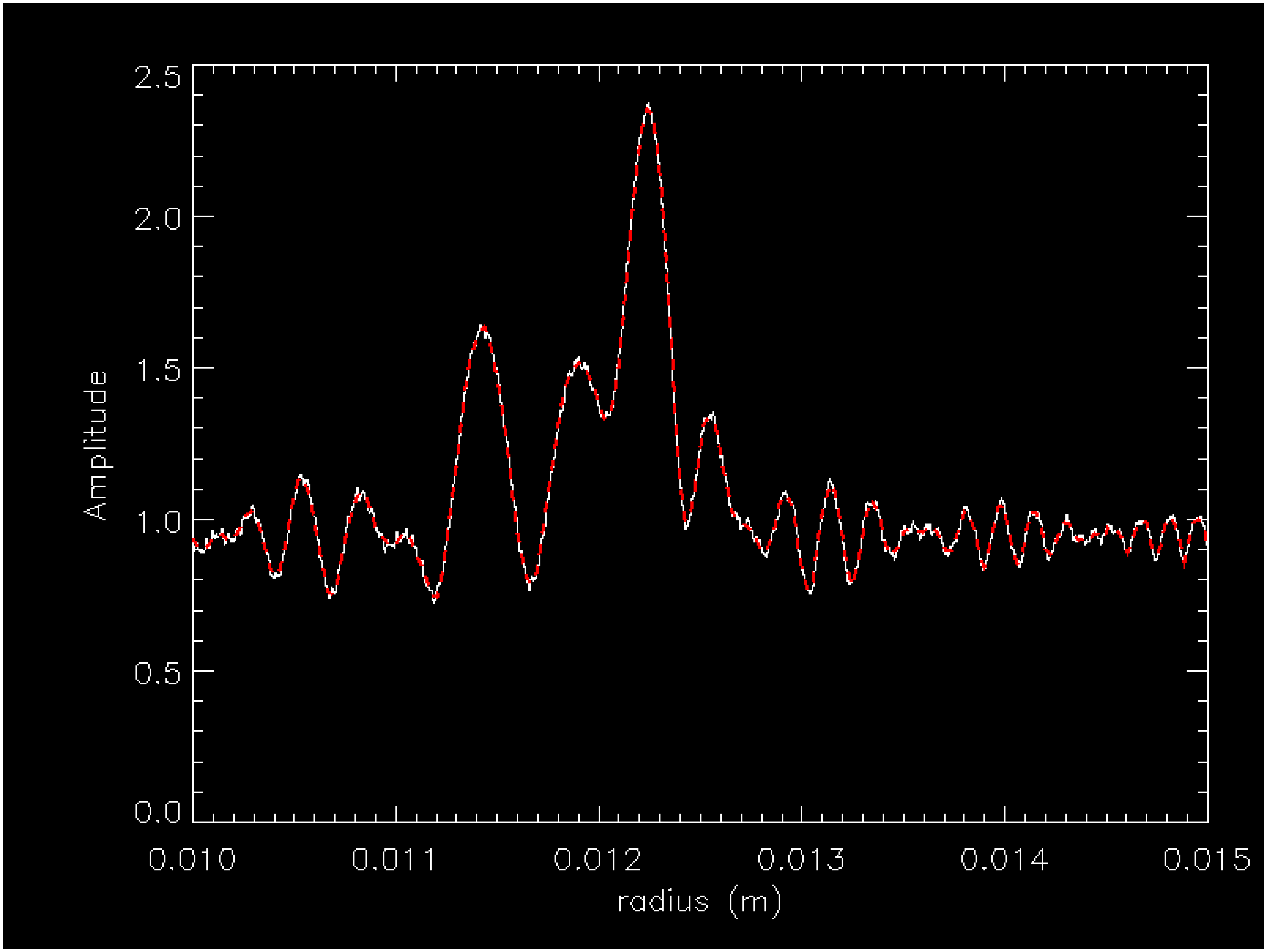


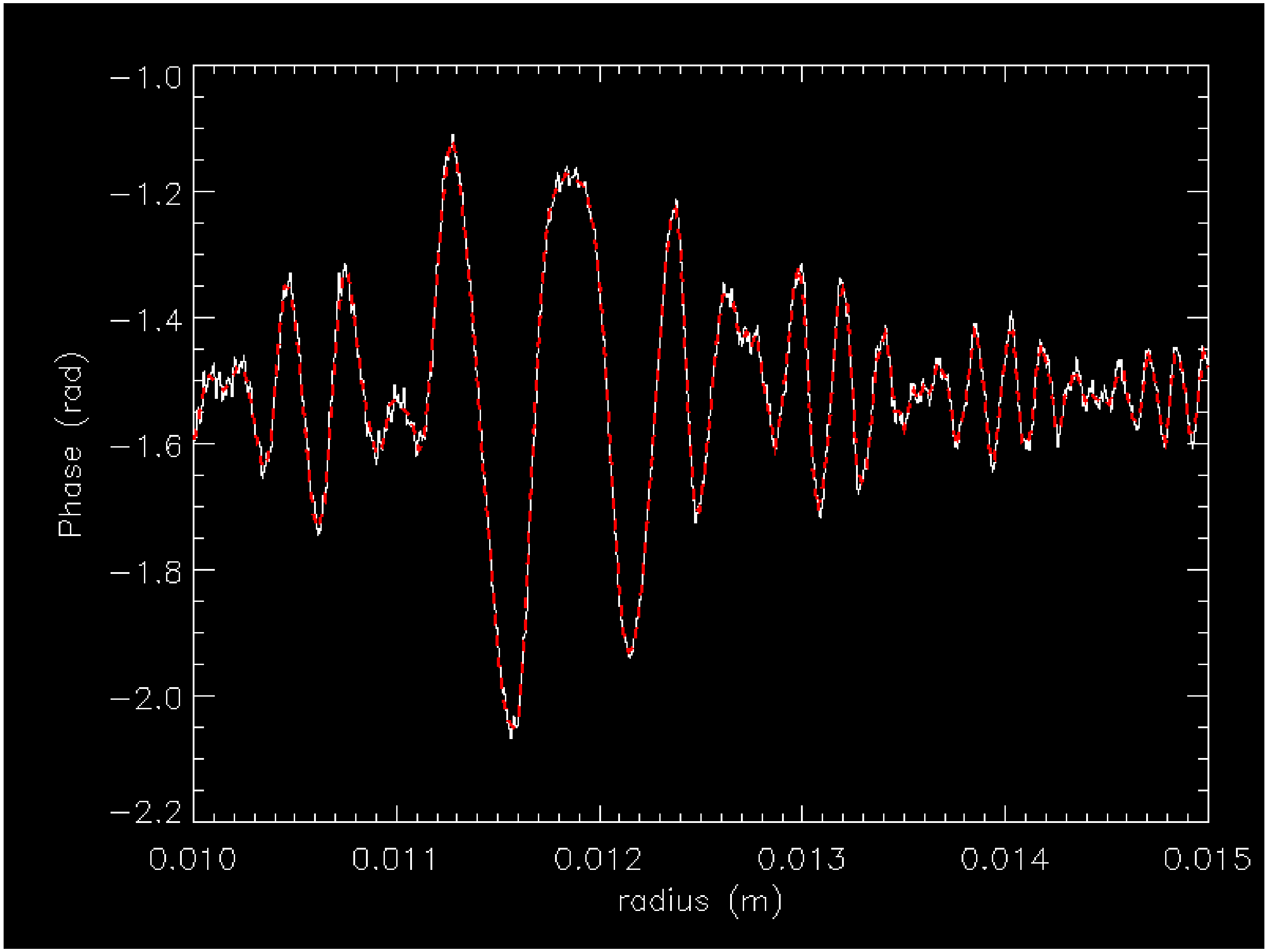
Obscured, large stroke





3
2
1
0
−1
−2
microns
0
5
10
15
20
25
mm


2.5
2.0
1.5
1.0
0.5
0.0
Amplitude
0.010
0.011
0.012
0.013
0.014
0.015
radius (m)



−1.0
−1.2
−1.4
−1.6
−1.8
−2.0
−2.2
Phase (rad)
0.010
0.011
0.012
0.013
0.014
0.015
radius (m)

ACAD Conclusions

- Fresnel propagators are accurate for ACAD (large stroke) DM solutions
- Current Fresnel-computed DM solutions for HLC from Moody are physically correct solutions
- Pueyo concurs